Appendix AI

Stephens, R.M. 2001. Migration, Habitat use, and Diet of Northern Goshawks *(Accipiter gentilis)* that winter in the Uinta Mountains, Utah. Masters Thesis, University of Wyoming, 63 pp.

Stephens, Robert M., Migration, habitat use, and diet of northern goshawks (*Accipiter gentilis*) that winter in the Uinta Mountains, Utah, M.S., Department of Zoology and Physiology, May 2001.

During the winters of 1998/99 and 1999/2000, I monitored 18 radio-telemetered northern goshawks. The objectives of my study were to examine the extent and timing of migration, determine if goshawks select habitat at the micro-site and/or landscape levels, describe the diet of wintering goshawks, and document causes of goshawk mortality.

Forty percent of marked males migrated and 90% of marked females migrated. The average distance of male and female migration was 15 km and 68 km, respectively. Fall migration occurred between late October and mid-December. Spring migration occurred between mid-January and late March. Most goshawks selected core winter ranges containing mixed-conifer forests similar to those used during the nesting season. Pinyon/juniper (*Pinus edulis-Juniperus osteosperma* and *Juniperus scopulorum*) woodlands were also important to wintering goshawks as six of twelve core ranges contained this habitat. At the micro-site level, goshawks selected forested landscapes with high canopy closure. At the landscape level, goshawk core winter ranges had higher densities of forest patches/km^2, vegetation types/km^2, and length of edge than random ranges but the differences were not statistically significant. Cottontails (*Sylvilagus spp.*) and black-tailed jackrabbits (*Lepus californicus*) were the primary prey identified at kill sites in pinyon/juniper woodlands and red squirrels (*Tamiasciurus hudsonicus*) were the primary prey identified at kill sites in mixed-conifer forests at higher elevations. Starvation and predation were the two main causes of mortality that I observed.

MIGRATION, HABITAT USE, AND DIET OF NORTHERN GOSHAWKS (*Accipiter gentilis*) THAT WINTER IN THE UINTA MOUNTAINS, UTAH

by
Robert M. Stephens

A thesis submitted to the Department of Zoology and Physiology
and The Graduate School of the University of Wyoming
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
ZOOLOGY AND PHYSIOLOGY

Laramie, Wyoming
May, 2001

Table of Contents

Chapter		Page
I.	Introduction	1
	The Northern Goshawk	1
	General Overview	4
	Study Area	5
II.	Migration of goshawks that nest in the Uinta Mountains, Utah	7
	Introduction	7
	Methods	8
	Results	9
	Discussion	11
III.	Winter habitat use of goshawks in the Uinta Mountains, Utah	18
	Introduction	18
	Methods	19
	Results	23
	Discussion	26
IV.	Diet of northern goshawks during the winter	35
	Introduction	35
	Methods	37
	Results	37
	Discussion	38
V.	Causes of mortality for goshawks in the Uinta Mountains, Utah	43

Introduction ... 43
Methods ... 44
Results ... 44
Discussion ... 46

VI. Project Summary ... 48

Literature Cited ... 51

Appendices ... 55

List of Figures

Figure		Page
1.1	Map of Study Area	6
2.1	Map of goshawk winter ranges and nest sites	17

List of Tables

Table		Page
2.1	1998/1999 Migration of marked goshawks	14
2.2	1999/2000 Migration of marked goshawks	15
2.3	Average days at winter range in 1998/1999	16
2.4	Average days at winter range in 1999/2000	16
3.1	Number of locations/goshawk used to estimate a home range	30
3.2	Size of winter ranges (km^2) for goshawks using a 50% polygon	30
3.3	Number of goshawk core winter ranges per habitat type and by sex	30
3.4	Percent of habitat types in home ranges vs. the study area	31
3.5	Percent of habitat types in each core winter range	32
3.6	Number of locations/goshawk used in the micro-site selection analysis	33
3.7	P-values from the one sample T-tests of the micro-site analysis	33
3.8	P-Values from the one sample T-tests of use locations versus home ranges for aspect	33
3.9	P-values for the paired T-tests from the micro-site analysis at kill sites	34
4.1	Diet of goshawks during the winter	42
5.1	Goshawk mortality	47

List of Appendices

Appendix		Page
A	1998/1999 Migration Patterns	55
B	1999/2000 Migration Patterns	57
C	Movements of individual goshawks during 1998/1999	59
D	Movements of individual goshawks during 1999/2000	61

CHAPTER I

The Northern Goshawk

The northern goshawk (*Accipiter gentilis*) is a large forest raptor occupying boreal and temperate forests in North America (Squires and Reynolds 1997). They seem to prefer mature forests with large trees and open understories for nesting habitat (Squires and Reynolds 1997). Goshawks, with their long tail and short, rounded wings, are morphologically adapted to the forested environments where they nest and hunt (National Geographic Society 1999).

I selected the goshawk as my study organism because of the speculation that goshawk populations are declining and the lack of information available about their winter ecology. Loss of nesting habitat is thought to be a major cause in the speculated decline of goshawk populations. The mature forests that goshawks nest in are economically valuable wood resources. These characteristics make their nest stands ideal locations for timber harvest. As timber harvest operations have decreased the amount of mature forests throughout the western U.S., it has been proposed that goshawk populations are declining. A study in Arizona indicated that goshawk populations in areas closely associated with timber harvest experienced drastic declines in nest reoccupancy and nestling production, estimated at 90% and 97%, respectively (Crocker-Bedford 1990). However, these results have been disputed on the basis of an inadequate sample design (Kennedy 1997).

The U.S. Fish and Wildlife Service (FWS) has been petitioned to list the goshawk as Threatened. Listing has been denied due to a lack of information documenting the speculated population decline. Goshawks were included on the U. S. Forest Service's (USFS) "Sensitive Species" list in the Pacific Southwest (1981), Southwest (1982), Intermountain (1992), Rocky Mtns. (1993), and Alaska (1994) regions; Northern, Eastern and Pacific Northwest regions do not list the species (Squires and Reynolds 1997). Sensitive species designation requires biological evaluations to consider potential impacts of proposed management actions (Squires and Reynolds 1997). Controversy over the impacts of forest management and the status of goshawk populations has increased research efforts investigating the ecology of this species. Most of the research has investigated the habitats used during the nesting season.

Goshawks typically nest in mature to old-growth forests composed primarily of large trees with high canopy closure (Reynolds et al. 1982). Nest areas are usually occupied from early March until late September (Reynolds et al. 1992). Foraging habitat that goshawks use during the nesting season has also been described. Goshawks in Arizona select foraging sites that had higher canopy closure, greater tree density, and greater density of trees >40.6 cm diameter at breast height (DBH) than on contrast plots (Beier and Drennan 1997). Good (1998) documents that male goshawks in Wyoming intensively use large areas of conifer forests interspersed with small natural openings in close proximity to nests.

Most of the information on prey selection of goshawks is also from studies during the nesting season. Goshawks are opportunists that kill a wide variety of prey, depending on the region, season, vulnerability, and availability (Squires and Reynolds 1997). The primary mammalian prey available to goshawks in Northern Utah includes snowshoe hares (*Lepus americanus*), cottontail rabbits (*Sylviagus nuttallii*), and red squirrels (*Tamiasciurus hudsonicus*) while the number of avian species is much more extensive (Graham et al. 1999).

Efforts to manage goshawks need to consider both nesting and winter habitat requirements (Squires and Ruggiero 1995). Goshawk wintering biology is almost completely unknown (Squires and Reynolds 1997). Limited information is currently available about whether goshawks migrate, what habitat they use, or which prey goshawks select during the winter. It has been recommended that forests be managed for abundant populations of prey species that are the goshawk's primary prey (Reynolds et al. 1992). Availability and abundance of prey often limits raptor populations (Reynolds et al. 1992). If the species goshawks prey on are to be managed for, further research is necessary to investigate these aspects of goshawk winter ecology.

In the United States, only a few studies have documented goshawk winter ecology. Squires and Ruggiero (1995) documented that four goshawks, which nested in southcentral Wyoming, were migratory. Doerr and Enderson (1965) estimated the abundance of goshawks in the foothills near Colorado Springs, Colorado during the winter. A study in the Uinta Mountains, Utah reported that six of 10 female goshawks were radio tracked and moved 100 km away from their nest sites into pinyon/juniper woodlands (Graham et al. 1999). Four females remained in their nest areas or in similar habitat less than 16 km away (Graham et al. 1999). The furthest known migration from this study was 300 km to the south (Squires 1997). In Arizona, Drennan and Beier (pers.comm.) reported that most females expanded their home ranges during the winter while most males migrated a short distance away to distinct winter ranges. These goshawks also specialized on either cottontails (*Sylvilagus spp.*) or Abert's squirrels (*Sciurus aberti*).

European studies provide most of the information on goshawk winter ecology (Kenward et al. 1981, Marcstrom and Kenward 1981, Widen 1981, 1984, 1985, 1987, and 1989). In Sweden, goshawks were partial migrants. Part of the population exhibited year-round fidelity to the nest territory while others migrated short distances. Fewer adult males were found to migrate than adult females (Kenward et al 1981 and Per Widen 1985). Widen (1988) reported that there was no major difference between autumn, winter, or spring in any aspect of habitat use.

Goshawks selected mature forest and large habitat patches but showed no major preference with respect to tree species composition (Widen 1985). Widen (1987) also reported a shift in prey selection between summer and winter. During the summer, avian species were the primary prey (86% of prey number) while squirrels were the primary prey (79% of prey number) during the winter. The applicability of these studies to goshawks wintering in the Rocky Mountains is unknown because they investigated a different subspecies of goshawk (*A. g. gentilis*) that lives in the human-dominated landscapes of Europe (Squires and Ruggiero 1995).

General Overview

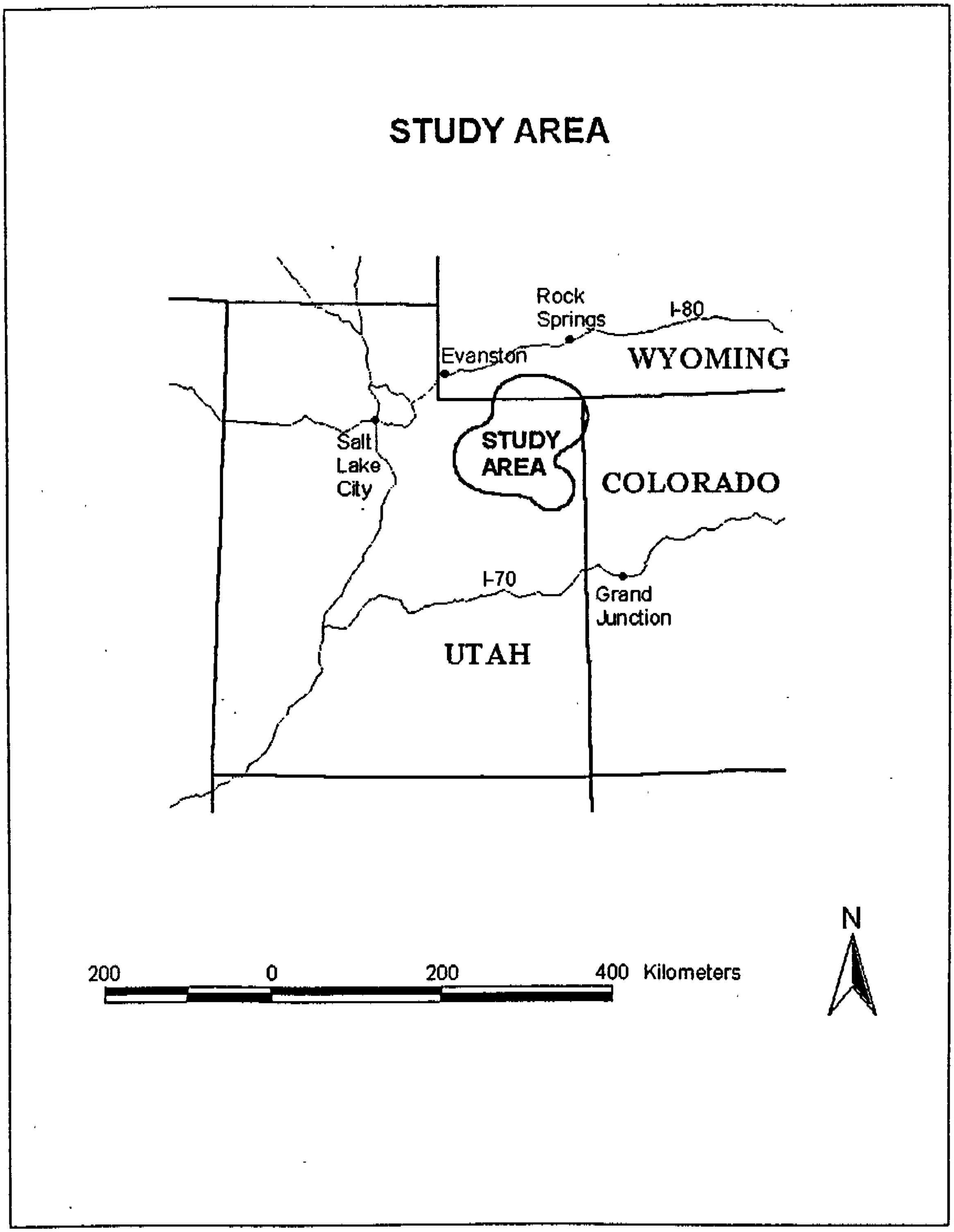
My study monitored goshawks in northeast Utah to investigate several aspects of their winter ecology. In Chapter Two, I discuss the extent and timing of migration for goshawks nesting in the Uinta Mountains, Utah. The location data set I used was collected during the winters of 1998/1999 and 1999/2000. In Chapter Three, I examine habitat use in the winter at both the micro-site and the landscape level. For the micro-site analysis I compared nine forest characteristics between night roosts and random sites, day roosts and random sites, kill sites and random sites, day roosts and night roosts, and all locations combined and random sites. In the analysis of landscape level selection, the characteristics I analyzed are patches/km^2, vegetation types/km^2, length of forest : non-forest edge, and dominant vegetation. In Chapter Four, I discuss the diet of goshawks during the winter. In Chapter Five, I document the causes of mortality for goshawks during the winter.

Study Area

The data presented in this thesis are from goshawks trapped at nest sites in the Ashley National Forest in the Uinta Mountains, Utah. The study area is approximately 16,000 km^2 (Fig. 1.1) of lands managed by the U.S. Forest Service, the Bureau of Land Management, the Uintah and Ouray Indian Reservation, the State of Utah, and private landowners.

Elevation of the study area ranges from ~1500 m to 4800 m. The predominant forms of vegetation on the study area are spruce-fir (*Picea engelmannii* and *Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), pinyon-juniper (*Pinus edulis-Juniperus osteosperma* and *Juniperus scopulorum*), agriculture, riparian woodlands, sagebrush grasslands and salt-desert scrub. The average annual precipitation is 70 cm (range 40 to 90 cm), with roughly equal precipitation the result of winter snowfall (November – April) and summer rains (May – October)(Ashcroft, G. L. et al. 1992).

Figure 1.1 Map of Study Area



CHAPTER II

MIGRATION OF GOSHAWKS THAT NEST IN THE UINTA MOUNTAINS, UTAH

Introduction

The limited information available on goshawks in North America suggests they are a partial migrant (Bloxton and Delap 1998, Kirkley 1999). A species is considered a partial migrant when part of the population remains year-round residents of an area while other individuals migrate (Welty and Baptista 1990). In southwestern Montana, research documented that many goshawks do not migrate, but spend the winter in the general region where they nested (Kirkley 1999). A study in western Washington tracked radio-tagged adult goshawks from their nest territories and found that males displayed stronger nest site fidelity during the winter season than females (Bloxton and Delap 1998). In southcentral Wyoming, the migration of four goshawks was tracked from their nest territories (Squires and Ruggiero 1995). All four goshawks migrated, and the extent of the known migration distances was between 65 km to 185 km. One of the furthest known migrations by a goshawk in North America was an adult female banded on 30 Sep on Hawk Ridge, MN and recovered on 30 Nov in Louisiana, a distance of 1,860 km (Evans and Sindelar 1974). Periodic invasions of goshawks have been observed along the western shore of Lake Michigan between 1950-74 (Mueller et. al 1977). The invasions were correlated with 10-year population declines in ruffed grouse (*Bonasa umbellus*) and snowshoe hare (*Lepus americanus*). The correlation likely indicates that this population of goshawks migrates when prey becomes scarce.

European studies provide most of the information published in peer-reviewed journals about goshawk winter ecology (Kenward et al. 1981, Marcstrom and Kenward 1981, Per Widen

1981, 1984, 1985, 1987, and 1989). Goshawks in Sweden are also partial migrants. Adult males typically wintered closer to their nest territory while adult females migrated further distances to winter ranges (Kenward et. al 1981, Per Widen 1985). Fewer adult males migrated than adult females, but juvenile males were the class most likely to leave (Kenward et al 1981 and Per Widen 1985).

The first objective of my study was to determine if goshawks that nest in the Uinta Mountains, UT are migratory. If so, I wanted to investigate the extent and timing of the migration, and determine if there are any differences in migration patterns between males and females.

Methods

Capture

Live and stuffed great horned owls (*Bubo virginianus*) were used as a lure to attract goshawks to dho-gaza nets (Bloom et al. 1992, McKlosky, J. T. and S. R. Dewey 1999). Transmitters were attached to the captured goshawk with a backpack-style teflon harness. The transmitters were equipped with a tipswitch that alternates the pulse rate by orientation. A slow pulse rate (~ 60 beeps/minute) indicates a perched bird and a fast pulse rate (~ 100 beeps/minute) indicates either a flying, eating or dead goshawk. Transmitter packages for male and female birds averaged 20 g and 26 g respectively. Goshawks were also banded with a US Fish and Wildlife Service aluminum leg band and a plastic, laminate, colored leg band with a unique alpha-alpha code.

Monitoring

I tracked goshawks equipped with radio-transmitters during the winters of 1998/99 and 1999/2000 from late October to mid-March. I began tracking in late October because I was first available to be at the field site at this time. Nest territories are usually occupied by mid-March (Squires and Reynolds 1997) so this time was defined as the end of winter.

I located marked goshawks by aerial and ground telemetry. A bird was only located once a day to insure independence of observations. An attempt was made to space relocations over the course of the day to ensure a representative sample of habitat use throughout the complete diurnal period. A field technician and I performed ground telemetry with hand-held yagi antennas. We approached goshawks until we were within approximately 100-500 meters, then split up, and attempted to triangulate a goshawks location with bearings that had an angle of intersection between 60-120 degrees. Finally, we walked in on the signal and attempted to see the goshawk before it flushed. A Cessna 206 equipped with a LORAN system was used to track marked goshawks from the air.

Results

Capture Success and Telemetry Accuracy

Eighteen (7 M and 11 F) adult goshawks were captured at their nest sites between 1997 and 1999. Seven marked goshawks (2 M and 5 F) were monitored during the winter of 1998/1999 (Appendix A). Fourteen marked goshawks (6 M and 8 F) were monitored during the winter of 1999/2000 (Appendix B). The average error of ground telemetry locations was 91.3 m (± 89.3 m). The average error of aerial telemetry locations was 762 m (± 450 m).

1998/99 and 1999/2000

During the course of two field seasons, I was able to locate the winter ranges of 14 (5 M and 9 F) goshawks (Figure 2.1). Three of the 14 were monitored during both the first and second field seasons. The migration patterns of those three were nearly identical during both winters so their movement data for only the first season is reported below (Appendices C & D). A goshawk was classified as migratory if its winter range did not include its nest stand. The migration distance was reported as the furthest distance a goshawk was located from its nest during the winter.

Eleven goshawks (2 M and 9 F) migrated while four goshawks (3 M and 1 F) wintered in their nest territories (Tables 2.1 and 2.2). Forty percent of marked males migrated and 90% of marked females migrated. The average distance between the nest stand and winter range for migratory goshawks was 55 km (n = 12). The average migration distance of males was 15 km and 68 km for migratory females. The furthest known migration was a female that was located 100 km from her nest stand. The direction of migration varied for migratory goshawks with no trends in any direction.

Nine goshawks (2 M & 7 F) migrated to elevations lower than their nest stands for part of the winter. Five goshawks (3 M & 2 F) wintered at elevations similar to their nest territories. The vegetation types of winter ranges at lower elevations were mainly pinyon/juniper (*Pinus edulis-Juniperus osteosperma* and *Juniperus scopulorum*) woodlands, agricultural areas mixed with pinyon/juniper and sagebrush (*Artemisia* sp.), and salt-desert scrub (*Atriplex* sp.) adjacent to a cottonwood (*Populus* sp.) riparian corridor. Winter ranges at the higher elevations were in similar forest types as nest territories which included lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziessi*), and spruce-fir (*Picea engelmanni* and *Abies lasiocarpa*).

Fall migration occurred between late October through late December. During the 1998/99 winter, one female migrated in late October, one male migrated in early November and four goshawks (3F and 1M) migrated in December. Four females migrated between November and December during the 1999/2000 field season. Spring migration occurred between mid-January through late March. During the 1998/1999 field season, one female returned to her nest in January, two females returned to their nests in February, and a male and a female returned to their nests in March. Three females returned to their nests in February and a male returned to his nest in March during the 1999/2000 winter.

The time a migratory goshawk spent at a winter range was reported as the median date the goshawk was last found in a nest territory and first found in a winter range until the median date between when the bird was last found in a winter range and first found back at the nest territory. Eighty-five days was the average time birds spent at a winter range during the 1998/99 field season (Table 2.3). Eight-two days was the average time spent on a winter range in the 1999/00 field season (Table 2.4).

Discussion

Goshawks exhibited similar patterns in the timing and extent of migration between both field seasons. My results also suggest that goshawks use the same winter range from year to year. Evidence for this comes from the three goshawks I tracked during both field seasons. Each bird migrated at approximately the same time as it did the previous year and returned to the same winter range.

Male and female goshawks had very different migration patterns. Females (~ 68 km) typically migrated further than males (~ 15 km). Also, a higher percentage of females (90%) migrated than males (40%). There are three hypothesis' that might explain the differences. First, males are the primary food providers for the pair and the nestlings during the nesting season. They probably know where the highest prey densities are, can hunt the nest territory more efficiently, and thus, they are less likely to migrate during the winter. Second, male goshawks may stay in winter because of the advantage of possessing a territory in early spring and subsequently breeding (Per Widen 1985). Third, males are substantially smaller than females and thus have smaller energy requirements. Therefore, it is likely that males are better able to cope with the resource bottlenecks that occur in nest territories during winter.

Most of the available information on goshawk migration in North America indicates adult goshawks do not migrate long distances which correlates with our results. Kirkley (1999) reported that five of eleven marked goshawks were found within 2 – 45 km of their nest sites during the month of January. I observed that 3 goshawks remained in their nest territories over winter while 12 goshawks migrated an average distance of 55 km between their nest stands and winter ranges. A study in western Washington tracked radio-tagged adult goshawks from their nest territories and reported that males displayed stronger nest site fidelity during the winter season than females (Bloxton and Delap 1998). I observed that only 40% of marked males migrated while 90% of marked females migrated. My observations also correlate with migration information of goshawks in Sweden. Widen (1985) reported that 20% of radio-tagged adult male goshawks and 50% of radio-tagged females moved out of the nest territory. However, I observed a higher percentage of both males and females that migrated.

Most goshawks migrated down in elevation to pinyon/juniper woodlands for part of the winter. This is an adaptation that has likely evolved to cope with the resource bottlenecks in nesting habitats since many of the avian prey species goshawks hunt during the nesting season migrate. Additionally, red squirrel populations, which are the dominant prey species of goshawks during the nesting season, are probably hammered during the nesting season down to levels which cannot sustain goshawks during the winter. Thus, I suggest that goshawks migrated to pinyon/juniper woodlands because prey availability was higher in these landscapes.

No goshawk nests have been located in pinyon/juniper woodlands in Utah (Graham et al. 1999). Therefore, current management efforts directed at maintaining sustainable goshawk populations do not consider the potential impacts of habitat alteration in pinyon/juniper woodlands to goshawk populations. My study has documented that pinyon/juniper woodlands are important to wintering goshawks, so management guidelines should be revised to include this habitat as important to goshawk viability. Possibilities for future research are to investigate in further detail how goshawks use these woodlands and investigate the relationships between prey densities at winter ranges for migratory and non-migratory goshawks.

Table 2.1 1998/1999 Migration of marked goshawks.

BIRD ID	SEX	MIGRATION DISTANCE	DEPARTURE DATE	RETURN DATE	MIGRATION DIRECTION	ELEVATION CHANGE
109	F	No migration	N/A	N/A	N/A	N
139	M	~ 15 km	Between 10/28/98 & 11/5/98	Between 3/10/99 & 3/14/99	S	Y
577	F	~ 70 km	Between 12/3/98 & 12/23/98	Between 1/07/99 & 1/13/99	E	Y
457	F	~ 70 km	Between 12/23/98 & 1/28/99	Between 3/14/99 & 3/18/99	W	N
698	F	> 100 km	After 10/26/98	Before 2/28/99	?	?
901	M	~ 14 km	Between 12/03/98 & 12/07/98	Mortality	SW	Y
931	F	~ 85 km	Between 12/02/98 & 12/22/98	Between 2/24/99 & 2/28/99	SW	Y

Table 2.2 1999/2000 Migration of marked goshawks.

BIRD ID	SEX	MIGRATION DISTANCE	DEPARTURE DATE	RETURN DATE	MIGRATION DIRECTION	ELEVATION CHANGE
011	F	~ 8 km	Between 12/14/99 & 12/16/99	Mortality	N	Y
029	M	No migration	N/A	N/A	N/A	N
049	F	~ 25 km	Between 11/16/99 & 12/09/99	On 2/08/00 & again on 3/23/00	SE	Y
069	M	No migration	N/A	N/A	N/A	N
089	F	?	?	?	?	?
139*	M	~ 15 km	(1) Before 11/03/99 & (2) Between 2/08/00 & 2/15/00	(1) Between 2/04/00 & 2/08/00 (2) Between 3/08/00 & 3/23/00	S	Y
577*	F	~ 70 km	Between 12/13/99 & 12/16/99	Between 1/13/00 & 1/29/00	E	Y
189	M	Mortality on 12/09/99	N/A	N/A	N/A	N/A
209	F	~ 90 km	Between 12/16/99 & 12/23/99	Between 2/23/00 & 2/29/00	S	Y
228	M	No migration	Before 11/17/99	Mortality	N/A	N
269	M	?	?	?	?	?
779	F	~ 100 km	Before 12/18/99	Between 1/13/00 & 1/24/00	E	Y
931*	F	~ 85 km	Before 11/17/99	Mortality	SW	Y
972	F	~ 65 km	Between 11/03/99 & 12/09/99	Between 3/08/00 & 3/22/00	SW	Y

* Goshawks monitored both winters.

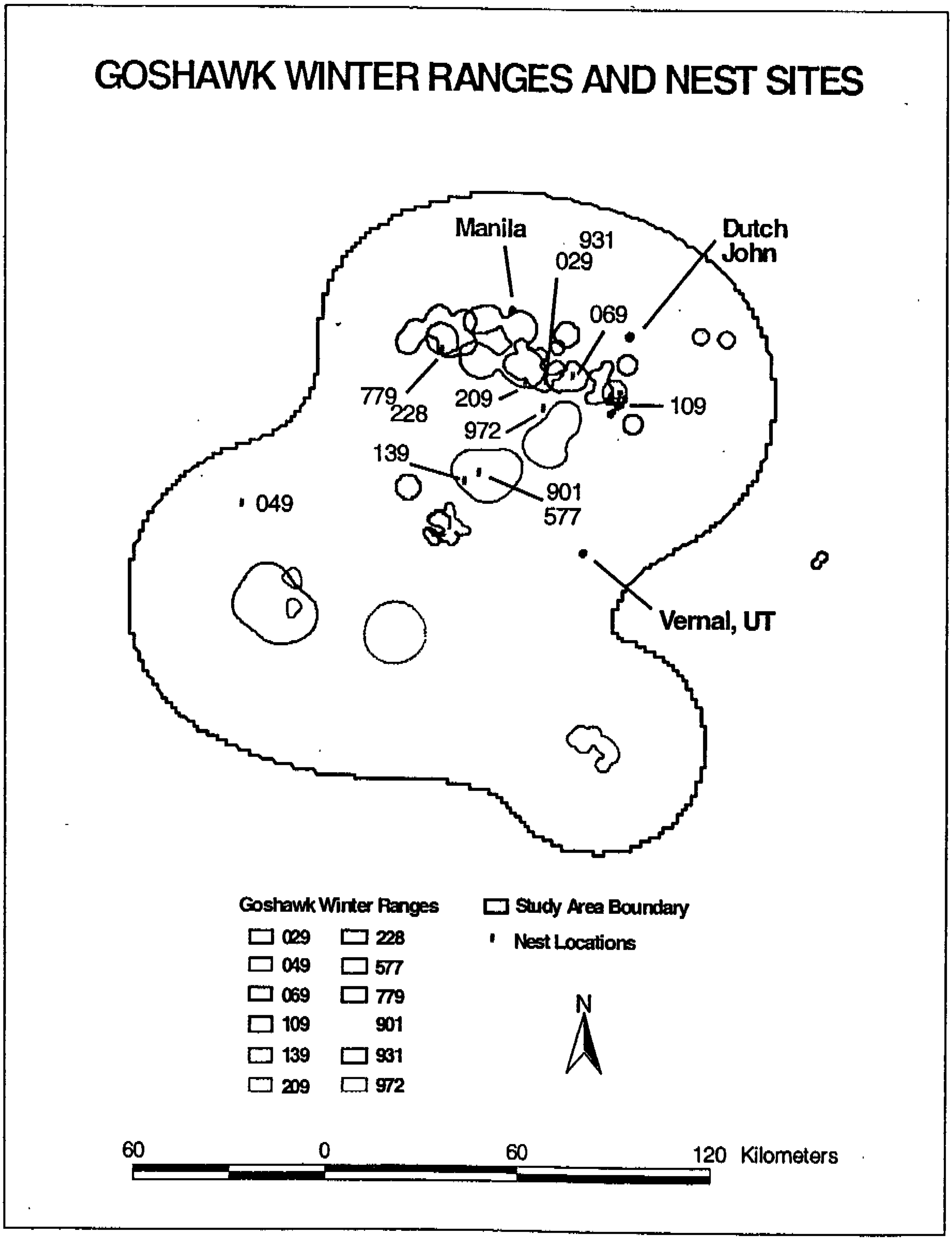
Table 2.3 Average days at winter range in 1998/1999.

BIRD ID	139	457	577	698	931	AVERAGE
DAYS AT WINTER RANGE	130	63	31	125	78	85

Table 2.4 Average days at winter range in 1999/2000.

BIRD ID	049	139	577	209	779	972	AVERAGE
DAYS AT WINTER RANGE	107	131	38	68	30	115	82

Figure 2.1 Map of goshawk winter ranges and nest sites.



CHAPTER III

WINTER HABITAT USE OF GOSHAWKS IN THE UINTA MOUNTAINS, UTAH

Introduction

Very little data exists in peer-reviewed journals on winter habitat use by goshawks in North America. However, Drennan and Beier (pers.comm.) observed that most marked goshawks in Arizona either migrated to winter ranges including pinyon/juniper woodlands or increased their home ranges to include this habitat. They observed that used plots had more medium-sized trees and denser canopy closure than contrast plots. Several other studies have reported observations of winter habitat use by goshawks. Squires and Ruggiero (1995) documented that four goshawks from southcentral Wyoming were migratory. These four goshawks were found wintering in habitats including aspen (*Populus tremuloides*) with mixed conifer stands, large stands of spruce/fir (*Picea engelmannii* and *Abies lasiocarpa*), and lodgepole (*Pinus contorta*), and cottonwood (*Populus* sp.) groves surrounded by sagebrush (*Artemisia* sp.). Goshawks in western Washington were reported to be generally sedentary during the winter and often maintained a close association with a breeding territory during the non-breeding season (Bloxton 1998). Kirkley (1999) reported that goshawks in southwestern Montana were foraging in open valley bottoms during the winter. A study in northeast Utah of the same goshawk population I studied made several observations of goshawk habitat use during the winter (Ashley National Forest 1998). Six of ten radio-telemetered female goshawks relocated to pinyon/juniper (*Pinus edulis-Juniperus osteosperma* and *Juniperus scopulorum*) woodlands near patches of cottonwoods during the winter. Four females in the same study remained in their nest areas or in similar habitat during the winter.

Additional information has been compiled from studies of goshawks in Europe. Widen (1985) reported that goshawks in Sweden select for mature forest and large habitat patches but showed no major preference with respect to tree species composition of the forest. No major differences were displayed between autumn, winter, or spring in any aspect of habitat selection (Widen 1988). Woodland within 200 m of open country was the most preferred habitat in England as the majority of kills were made there (Kenward 1982). The author suggests this preference was probably because of the high prey availability at the edge habitat (Kenward 1982).

Management objectives to maintain sustainable goshawk populations only manage the habitats used during the nesting season. These habitats fulfill various requirements of nesting goshawks such as maintaining healthy prey populations, adequate forest structure suitable for hunting goshawks, and suitable nesting habitat. If goshawks use different habitat in the winter than in the nesting season, current management efforts could be insufficient at maintaining viable goshawk populations. Therefore, the second objective of my study was to describe winter habitat use of goshawks in the Uinta Mountains, Utah. I examined habitat use at two levels; the micro-site and the landscape level (Johnson 1980). Landscape level selection is the selection of a home range from within a geographical range. Micro-site selection is the selection of various habitat characteristics within the home range.

Methods

Home Range Analysis

Home ranges estimates were based on locations obtained from aerial telemetry and ground telemetry. An attempt was made to evenly spread relocation efforts over time but this was not always possible due to the difficulty in accessing some winter ranges, locating goshawks, and inclement weather. Home ranges were estimated with a kernal estimator in ArcView 3.2 (ESRI inc. 1996). My goal was to document the characteristics of core areas in goshawk winter ranges so all home range estimates were of 50% polygons. The study area boundary was based on a 95% polygon estimated with a kernal estimator of all goshawk winter locations pooled together.

Landscape

Mean patch density/km^2, the mean number of vegetation types/km^2, the mean length of forest edge (km/km^2), and dominant vegetation are the characteristics I analyze in the landscape selection analysis. I use ArcView 3.2 to perform the analyses. The analysis of mean patch density/km^2, mean number of vegetation types/km^2, and mean edge length are performed by comparing 12 goshawk core ranges to 12 random ranges of equal size. I use MiniTab 12.23 to perform the paired t-tests and with an $\alpha = 0.05$. I estimate dominant vegetation by pooling the percentages of each vegetation type for all goshawk winter ranges. Then I compared the percentages of each vegetation type in the core ranges to the study area. The vegetation layer I use is combined from the Utah (USGS National Gap Analysis Program 1995), Colorado, and Wyoming GAP analysis (Merrill et al. 1996). Overall map accuracy of the vegetation layer from the Utah GAP analysis is 75.3% (USGS National Gap Analysis Program 1995).

Micro-habitat

The analysis of micro-habitat was performed on locations obtained by ground telemetry and visual observations. Four comparisons were made of the habitat characteristics using a one sample *t*-test with a family $\alpha = 0.10$ and a Bonferroni adjusted $\alpha = 0.015$: (1) all use sites to random sites, (2) night roost sites to random sites, (3) day sites to random sites, and (4) day roost sites to night roost sites. Kill sites were also compared to random sites. Due to the limitations of a small sample size, kill sites were classified into two groups. First, all kill sites from pinyon/juniper forests were pooled together and compared to random locations. Second, all kill sites from mixed-conifer forests (lodgepole pine, Douglas-fir [*Pseudotsuga menzieseii*], ponderosa pine [*Pinus ponderosa*], and subalpine fir [*Abies lasiocarpa*]) were pooled together and compared to random locations. A paired t-test with an $\alpha = 0.10$ and a Bonferroni adjusted $\alpha = 0.015$ was used because the number of tests was nine.

I measured habitat characteristics on a 0.10-acre circular plot using the Point-Quarter technique (Cottam and Curtis 1956). The habitat characteristics I analyzed were canopy closure, tree density, tree height, tree diameter at breast height (DBH), pinyon/juniper (PJ) canopy, sapling density, shrub density, aspect and slope. I measured canopy cover with a vertical sighting tube at 20 points along the perimeter of the plot (James and Shugart, 1971). The closest tree to the center tree in each quadrant was measured for height and tree DBH. Tree height was measured with a clinometer. An index of density was obtained by measuring the distance from the center tree to the closest tree, sapling, and shrub in each quadrant. DBH was measured with a DBH tape. Trees were classified as > 3.0 inches DBH. Saplings were classified as < 3.0 inches DBH. It was difficult to measure the DBH of pinyon pines and juniper trees because they grow from many shoots emerging out of the soil. Instead, I used the canopy diameter of the tree for a measurement I called "PJ Canopy". Pinyon pines and junipers > 6 feet tall and > 36 inches in canopy diameter were considered trees. Pinyons and junipers were classified as saplings if they were either < 6 feet tall or < 36 inches of canopy diameter. Slope was estimated with a "Slope Estimator" on a compass. Selection of aspect was analyzed by comparing the aspect of goshawk locations to the average aspect of the home range for eight categories of aspect. Aspect data were derived from the National Elevation Dataset (NED) and analyzed with ArcView 3.2. The eight categories of aspect I used were: (1) 337-22 (2) 22-67 (3) 67-112 (4) 112-157 (5) 157-202 (6) 202-247 (7) 247-292 (8) 292-337. The aspect analysis was done with a one sample t-test and a Bonferroni adjusted $\alpha = 0.015$ because the number of tests was eight.

If a goshawk's location was estimated by triangulation, I located the plot center by following a Precision Location GPS Receiver (PLGR) to the coordinates. PLGR's removed the error induced by the military. During my second field season, the military quit scrambling satellite signals. Afterwards, I used a Garmin GPS 12. Once the GPS indicated I was at the plot center, the closest tree within 50 m was used as the center tree. These points were "Use" plots and they were compared to "Random" plots. I located random plots by spinning a compass to obtain a random direction and walking 500 m in that direction. The closest tree within 50 m of the transect's end was selected as the plot center. When the closest tree was greater than 50m from the plot center, I measured habitat characteristics at the point where the GPS determined the plot center. Plots without trees were ultimately withdrawn from the analysis because a much higher number of random plots were treeless compared to use plots.

Methods for ground telemetry are presented in Chapter 2. Night roost sites were located in a similar manner except that we approached the signal after sunset. Goshawks are less likely to flush at night so we approached the signal until we were within ~ 100 m, separated, and triangulated on the signal to obtain a location.

I located kill sites with the aid of the tipswitches installed in the transmitters. The tipswitches caused the pulse rate to vary by horizontal and vertical orientation. A slow pulse rate indicated a perched bird. A fast pulse rate indicated either a flying, eating or dead goshawk. If the signal pulse rate was fast, and the signal direction and intensity remained constant, a goshawk was usually foraging at a kill site. I then walked towards the signal as fast as possible and attempted to get a visual on the goshawk.

Results

Home Range Analysis

I estimated home ranges for 12 goshawks based on locations from aerial telemetry, ground telemetry, and visual observations. The average error associated with aerial telemetry and ground telemetry was 763 m and 92 m, respectively. Nine relocations were the minimum used to estimate a home range and the average was 24 locations (Table 3.1). The average 50% polygon home range size was 25.8 $km^2 \pm 25.3$ km^2 (Table 3.2).

Landscape

The mean patch density was 1.249/km^2 for goshawk winter ranges and only 0.680/km^2 for the random home ranges. However, the difference was not significant ($p = 0.135$). A power analysis revealed that I only had a 29% chance of detecting a significant difference given the sample size, standard deviation, and alpha = 0.05. The number of vegetation types was 0.518/km^2 in goshawk core ranges and 0.343/km^2 in random home ranges. The difference in vegetation types/km^2 was not significant ($p = 0.090$). A power analysis revealed that I only had a 14% chance of detecting a significant difference. The average length of edge in goshawk core ranges and random ranges was 2.958 km/km^2 and 2.128 km/km^2, respectively. The difference was not significant ($p = 0.100$). A power analysis revealed that I only had a 32% chance of detecting a significant difference.

I identified four core range habitat types: (1) mixed-conifer forests at higher elevations composed primarily of lodgepole pine, subalpine fir, and/or Douglas-fir, (2) woodlands composed primarily of pinyon/juniper and agricultural areas adjacent pinyon/juniper woodlands, (3) a combination of the first two core range habitat types, and (4) lowland riparian areas adjacent to salt-desert scrub. Male and female goshawks displayed no obvious differences in the use of the various habitats I identified in winter ranges. Four goshawks (3F and 1M) had core ranges in mixed-conifer forests, four goshawks (1M and 3F) had core ranges in woodlands composed of mainly pinyon/juniper and agricultural areas adjacent to pinyon/juniper woodlands, three goshawks (3M) had core ranges composed of conifer and pinyon/juniper woodlands, and one goshawk (1F) had a core range in lowland riparian habitat adjacent to salt-desert scrub (Table 3.3).

Lodgepole pine and mountain fir were present in much higher percentages in goshawk core ranges than in the study area (Tables 3.4 and 3.5). Seven of twelve core ranges contained at least one of these two habitat types. Oak, ponderosa pine, and lowland riparian were also present in core ranges at higher percentages than in the study area. However, they were only present in one, four, and two core ranges of 12, respectively. Sagebrush was the dominant vegetation in core winter ranges (28.7%) but was selected in lower percentages than its availability in the study area (32.5%). Pinyon/juniper woodlands and agricultural habitats were used in approximately equal proportion to availability. Six of twelve core ranges contained pinyon/juniper woodlands and three core ranges contained landscapes with agriculture. Aspen, dry meadow, salt-desert scrub, and a catch-all category referred to as 'other' were present in core ranges at lower percentages than in the study area.

Micro-Site

A total of 138 locations was collected from 10 birds during two winters. These locations were collected by ground telemetry and visual observations during both field seasons. The average error of our ground telemetry locations was 92 m. A characteristic of these locations is that a higher number of use plots occurred in forested environments than in random plots. Four of 138 use plots were in non-forested environments while 35 of 138 random plots were in non-forested environments. This also indicates that use plots are commonly located near non-forested areas. To make a more meaningful comparison of forest characteristics between use and random plots, plots without trees present were excluded from the analysis. A total of 108 locations from 10 marked goshawks (Table 3.6) was suitable for the micro-site analysis. Our estimates of habitat use within the winter range could be biased due to irregular sampling methods. An attempt was made to evenly distribute relocation efforts over time but this was not always possible due to the difficulty in accessing some winter ranges and locating goshawks.

In my analysis of all use plots to random plots, use plots had significantly higher canopy closure ($p = 0.002$). No significant differences were detected between use and random plots for tree density, tree DBH, PJ canopy, tree height, sapling density, shrub density, slope (Table 3.7) and aspect (Table 3.8).

Night roost sites also had significantly higher canopy cover ($p = 0.0004$) than random plots. No significant difference was detected between use and random plots for tree density, tree DBH, PJ canopy, tree height, sapling density, shrub density. The comparison of night roosts to day roosts revealed no significant differences.

Day use sites were higher than random sites for canopy closure ($p = 0.0043$) and tree density ($p = 0.008$). No significant difference was detected between use and random plots for tree DBH, PJ canopy, tree height, sapling density, or shrub density.

No significant differences were detected between kill sites in either conifer forests or pinyon/juniper forests and their paired random plots (Table 3.9).

Discussion

The average size of core use winter ranges for wintering goshawks was 25.8 $km^2 \pm 25.3$ km^2. It is important to note that my home range estimates could be biased due to relocations that were unevenly spaced temporally. Winter range size was highly variable as it ranged from 1.0 km^2 to 79.5 km^2 for 12 goshawks. The large variance was partially attributed to three goshawks with large home ranges (26.1 km^2, 79.5 km^2, and 53.9 km^2) that wintered in landscapes fragmented by agriculture. However, the size difference between goshawks core ranges containing agriculture those not containing agriculture was not significant (2 sample *t*-test; $p = 0.14$). These larger winter ranges were likely a function of fragmentation and prey availability. Goshawks in agricultural landscapes probably had to cover larger amounts of land to make an adequate amount of kills. While the edge habitat in those fragmented landscapes appeared to have relatively high densities of prey, winter ranges containing agricultural fields have a higher percentage of unsuitable habitat for prey species such as cottontails. With those three goshawks removed, the average size of core use home ranges was reduced to 15.96 $km^2 \pm 16.16$ km^2. A study of goshawks in Sweden reported the size of goshawk winter ranges was a function of prey availability (Kenward et al. 1981). At Frotuna, Sweden where pheasants were released, the average goshawk home range was 20 km^2 while at Segersjo, were only wild pheasants were present, the average goshawk home range was 54 km^2. In England, range size was related to the proportion of a range that was woodland edge, and to prey availability (Kenward 1982).

Inside of home ranges, goshawks selected for forested areas with high canopy closure. Goshawks exhibit selection for high canopy closure during the nest season also (Reynolds et al

1982, and Beier and Drennan 1997). These areas provide adequate perch sites to scan for prey, and forest structure suitable for goshawks to fly through and ambush prey.

At the landscape scale, goshawk core ranges had a higher estimated mean patch density/km^2 than random ranges but the difference was not significant. A power analysis revealed that I only had a 29% chance of detecting a significant difference given the sample size, standard deviation, and alpha = 0.05. The estimated number of vegetation types/km^2 in goshawk winter ranges was higher than was found in random home ranges but the difference was not significant. A power analysis revealed that I only had a 14% chance of detecting a significant difference. The estimated mean length of forest edge in goshawk core ranges was higher than in random ranges but the difference was not significant. A power analysis revealed that I only had a 32% chance of detecting a significant difference. Even though the analysis of these characteristics found no statistically significant differences, it is important to note that each characteristic was near statistical significance and that both a small sample size and the coarseness inherent in GAP vegetation classification limited the analysis. Therefore, a trend may have been present but undetected, in which goshawks used more diverse landscapes than are randomly found. Home ranges with higher diversity of vegetation types and numbers of patches would likely increase the richness of the prey base during a period when it most limited.

Studies and surveys over the past 20 years indicate that the goshawk occurs across Utah in a wide variety of forest types (Graham et. al 1999). Goshawks appear to use a greater variety of habitat types during the winter than the nesting season. I observed wintering goshawks in habitats including Douglas-fir, ponderosa pine, subalpine fir and lodgepole pine, pinyon/juniper woodlands, cottonwood riparian corridors adjacent to salt-desert scrub, and agricultural landscapes. Goshawks appeared to show the highest selection of core winter ranges that contained mountain fir and lodgepole pine. Seven of twelve core winter ranges contained at least one of these two habitats. These habitats are also intensively used by goshawks during the nesting season. Current management efforts aim to maintain viable goshawk populations through managing these nesting season habitats at three scales; the nest stand, the post-fledgling area , and the foraging area (Reynolds et al. 1992). Efforts to maintain suitable forest conditions at the scale of the foraging area likely provides the greatest benefit to wintering goshawks. Foraging areas adjacent to nest stands are managed to be productive for a variety of prey species that are present in the summer. During the winter, squirrels are the main prey in these forests. This raises the question of whether or not management efforts in these landscapes should put more emphasis on red squirrel productivity. A suggestion for future research would be to investigate the relationship between goshawk migration and squirrel densities.

Pinyon/juniper woodlands appear to be another important habitat of wintering goshawks. Six of twelve goshawks had core winter ranges containing pinyon/juniper woodlands and an additional three goshawks were located in this habitat during part of the winter. No nests have been located in Utah in this vegetation type (Graham et al. 1999) so management efforts to maintain sustainable goshawk populations do not currently consider pinyon/juniper woodlands. Cottontails were the primary prey species I found at kill sites in this habitat. Indications are that goshawks are normally not limited by nesting habitat but by food availability (Widen 1988). Meeting the habitat requirements of wintering goshawks in this habitat could be just as important as meeting the needs of goshawks in their nesting season habitat. As a result of the high use of pinyon/juniper woodlands in northeast Utah by wintering goshawks, I recommend that future management activities in this habitat evaluate potential impacts to goshawk sustainability.

Pinyon/juniper is regarded as the late successional species in landscapes where it occurs. No other landscape is so dominated by the late successional species as here (Graham et al. 1999). It is believed to be useful for prey to increase the other seral stages where pinyon/juniper occurs (Graham et al. 1999). Early and mid-seral stages are productive and support many of the birds taken by goshawks, along with black-tailed jackrabbits (Graham et al. 1999). Pinyon/juniper woodlands are a difficult vegetation to manage (Graham et al. 1999). Throughout Utah, there have been various attempts to transform many of these woodlands to earlier successional stages with limited success (Graham et al. 1999). Pinyon/juniper woodlands occupy approximately 50% of forest and woodlands in Utah (Graham et al. 1999). Even though it is the predominant forest type in Utah, it is unknown whether or not these woodlands are limiting for goshawks. We are just now discovering that pinyon/juniper woodlands are important for wintering goshawks and do not know the full extent of dependency upon this habitat by wintering goshawks. The two winters of my study were relatively mild. It could be possible that during harder winters, a higher proportion of goshawks migrate to this habitat and winter there for longer periods.

Table 3.1 Number of locations/goshawk used to estimate a home range.

BIRD ID	029	049	069	109	139	209	228	577	779	901	931	972	Sum
Number of Locations	25	18	29	27	39	15	21	22	9	23	26	30	284

Table 3.2 Size of winter ranges (km^2) for goshawks using a 50% polygon.

BIRD ID	029	049	069	109	139	209	228	577	779	901	931	972	$\bar{X}$
Km^2	7.4	4.4	13.1	1.0	3.8	8.0	26.1	47.6	13.4	33.4	79.5	53.9	25.8

Table 3.3 Number of goshawk core winter ranges by vegetation type and by sex.

	Mixed-Conifer	Mixed-Conifer & PJ	PJ and Agriculture	Lowland Riparian
Number of Goshawks and Sex	3F & 1 M	3M	3F & 1M	1F

Table 3.4 Percent of vegetation types in goshawk core ranges vs. the study area.

#	HABITAT TYPE	CORE RANGE	STUDY AREA
1	Sagebrush	28.7%	32.5%
2	Lodgepole Pine	22.3%	9.8%
3	PJ	16.5%	16.7%
4	Salt-Desert Scrub	11.5%	13.9%
5	Mountain Fir	7.5%	1.9%
6	Agriculture	7.2%	8.0%
7	Ponderosa Pine	2.2%	0.9%
8	Lowland Riparian	2.2%	0.4%
9	Oak	1.8%	0.2%
10	Dry Meadow	0.1%	0.5%
11	Aspen	0.0%	1.7%
12	Other*	0.0%	13.5%

* includes: spruce-fir, water, grassland, alpine, wet meadow, barren, mountain riparian, urban, greasewood, and wetland patches.

Table 3.5 Percent of vegetation types in each core winter range.

Bird ID	029	049	069	109	139	209	228	577	779	901	931	972
Pond pine	17.1	0	0	0	0	0	0	7.0	0	2.2	0	0.4
Lpp pine	16.3	0	49.0	79.8	0	0	1.5	70.8	43.4	6.9	0	0
Mtn. fir	20.4	0	16.2	0	0	0	17.6	11.8	0	23.7	0	0
PJ	2.0	62.0	0	0	38.0	0	13.9	0	0	33.1	48.8	0
Aspen	0	0	0	0	0	0	0	0.5	0	0	0	0
Oak	0	0	0	0	20.8	0	0	0	0	0.4	0	0
Sage	44.2	21.7	34.8	20.2	41.2	0.0	66.9	9.9	55.1	33.7	11.2	5.2
Dry Mdw.	0	0	0	0	0	0	0	0	1.4	0	0.1	0
Low. Ripar.	0	0	0	0	0	26.8	0	0	0	0	0	0
Agric.	0	16.3	0	0	0	0	0	0	0	0	39.9	30.1
Salt-Desert Scrub	0	0	0	0	0	73.2	0	0	0	0	0	64.3
Other	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.6 Number of locations/goshawk used in the micro-site selection analysis.

BIRD ID	029	049	069	109	139	228	577	901	931	972	Sum
Kill sites	2	1	4	2	1	3	2	1	2	5	23
Night roosts	0	0	4	0	0	4	0	2	0	3	13
Total Plots	11	7	14	13	6	9	9	11	12	16	108

Table 3.7 P-values from the one sample *t*-tests of the micro-site analysis ($\alpha = 0.015$).

	Canopy Closure	Tree Density	Tree DBH	PJ Canopy	Tree Height	Sapling Density	Shrub Density	Slope
All – Random	0.002	0.034	0.26	0.66	0.14	0.074	0.75	.082
Night – Random	0.0004	0.48	0.41	0.29	0.32	0.83	0.63	
Day – Random	0.0043	0.008	0.31	0.97	0.2	0.12	0.82	
Night – Day	0.13	0.33	0.33	0.99	0.57	0.72	0.95	

Table 3.8 P-Values for the one sample *t*-tests of use versus home ranges for aspect ($\alpha = 0.015$).

Aspect in degrees	337-22	22-67	67-112	112-157	157-202	202-247	247-292	292-337
P Value	0.32	0.049	0.33	0.54	0.74	0.21	0.19	0.44

Table 3.9 P-values for the paired t-tests from the micro-site analysis of kill sites ($\alpha = 0.015$).

	Canopy Closure	Tree Density	Tree DBH	PJ Canopy	Tree Height	Sapling Density	Shrub Density
Conifer kill sites - Random	0.042	0.307	0.036	N/A	0.18	0.108	0.74
PJ kill sites – Random	0.37	0.454	N/A	0.77	0.54	0.037	0.063

CHAPTER IV

DIET OF NORTHERN GOSHAWKS DURING THE WINTER

Introduction

Goshawks are opportunists that hunt a wide variety of prey (Squires and Reynolds 1997). The hunting technique used by goshawks is described as 'short-stay perch-hunting' i.e. short movements between perches, where they stay for longer periods, and from which nearly all hunting attacks are launched (Widen 1984).

The diet of goshawks during the nesting season is well documented (Boal and Mannan 1994, Good 1998, Reynolds 1982, Watson 1998). A study in southcentral Wyoming documented that the dominant prey item delivered to nests by adult goshawks was red squirrels (*Tamiasciurus hudsonicus*; Good 1998). In Washington, Douglas' squirrels (*Tamiasciurus douglasii*), blue and ruffed grouse (*Dendragapus obscurus* and *Bonasa umbellus*) and snowshoe hare (*Lepus americanus*) were the most frequently killed prey during the nesting season (Watson et al. 1998).

Many of the prey species available to goshawks during the nesting season either migrate or hibernate during the winter. Thus, the diversity of prey species available during the winter is limited. Like other aspects of goshawk winter ecology, limited information is available on the diet of wintering goshawks in North America. Drennan (pers.comm.) observed that marked goshawks in Arizona were preying on either Abert squirrels (*Sciurus aberti*) or desert cottontails (*Sylvilagus audubonii*) during the winter. Most of the information on goshawk prey selection in the winter comes from European studies. Widen (1987) reported that goshawks in Sweden make a diet shift between summer and winter. Avian prey species were the dominant prey during the nesting season while squirrels were the dominant prey in winter. Kenward et al. (1981) also documented that red squirrels were the most frequently taken prey in Sweden during winter. Hares (2,700 – 3,670 g) were the largest prey goshawks were documented killing and they were also the only prey taken more frequently by females than males (Kenward et al 1981).

Other estimates of prey hunted by wintering goshawks are limited to speculation made from general observations of habitat use. Squires and Ruggiero (1995) tracked the migration of three goshawks during winter. Habitats they were located in ranged from aspen with mixed conifer stands, large stands of spruce/fir and lodgepole, and cottonwood groves surrounded by sagebrush. Inferences can be made that those goshawks were likely hunting red squirrels and cottontails since they are likely the most abundant prey in those habitats. Six of 10 female goshawks radio tracked in the Uinta Mountains relocated to pinyon/juniper woodlands near patches of cottonwood during the winter (Ashley National Forest 1998b). Four females remained in their nest areas or in similar habitat less than 10 miles away. Inferences can also be made from these observations that those goshawks might be preying on red squirrels and cottontails since they are also likely the most abundant prey in those two habitat types in winter.

Widen (1985) suggests that goshawks are not normally limited by nesting habitat but by food availability. Hunting success depends not only on prey density but also to a great degree on different habitat features determining the ability to hunt (Widen 1988). If so, foraging habitat may be more important than nesting habitat for goshawks in boreal forests. A goal of current forest management on USFS lands is to manage landscapes for the prey species goshawk hunt during the nesting season. Reynolds et al. (1992) recommended that forests surrounding the nest stand (~ 5,400 acres) be managed to support diverse prey populations. If goshawks hunt different prey species in the winter than in the nesting season, then current management efforts might be insufficient. Therefore, the third objective of my study is to describe diet of goshawks during the winter.

Methods

Kill sites were found during our efforts to locate marked goshawks as described in Chapter 2. We recognized a goshawk was at a kill site from a distinctive signal emitted by a transmitter when the goshawk was eating. Transmitters contained tipswitches that cause the pulse rate to vary with either horizontal or vertical orientation. A slow pulse rate indicated a perched bird. A fast pulse rate indicated either a flying, eating or dead goshawk. When the pulse rate was fast and the signal's direction and intensity remained constant, a goshawk was usually foraging at a kill site. We then walked towards the signal as fast as possible and attempted to visually observe the goshawk. Prey remains were identified at the kill site when the goshawk was observed.

Results

Over the period of two field seasons, I located a total of 23 kill sites (Table 4.1). Cottontails (*Sylvilagus sp*.; n = 9) and pine squirrels (*Tamiasciurus hudsonicus*; n = 9) were the most common prey found at kill sites. Six cottontail kill sites were found in pinyon/juniper (*Pinus edulis-Juniperus osteosperma* and *Juniperus scopulorum*) woodlands and three were found in Douglas-fir (*Pseudotsuga menziesii*) forests. All pine squirrel kill sites were found in mixed-conifer forests composed of lodgepole pine (*Pinus contorta*), Douglas-fir, subalpine fir (*Abies lasiocarpa*), or ponderosa pine (*Pinus ponderosa*). Other kills included two black-tailed jackrabbits (*Lepus californicus*), a ruffed grouse (*Bonasa umbellus*), a snowshoe hare (*Lepus americanus*), and a starling (*Sturnus vulgaris*).

I observed a high degree of dietary overlap between males and females. Red squirrels accounted for 42 % (5/12) of the kill sites of female goshawks and 36 % (4/11) of the kill sites of male goshawks. Cottontail rabbits accounted for 33 % (4/12) of the kill sites of female goshawks and 45 % (5/11) of the kill sites of male goshawks.

I made a unique observation of a female goshawk that wintered near Bonanza, Utah. She night roosted along the White River corridor in cottonwoods (*Populus spp.*) and was observed hunting in the adjacent salt-desert scrub during the day. I observed her perched on a dirt incline that provided a vantage point of the area and suspect that she was monitoring the area for cottontails and jackrabbits. This point was ~ 1 km away from the closest stand of trees which is interesting because it documents a goshawk hunting away from forested habitat.

Another unique observation occurred when I saw a male goshawk stooping on a male Northern Harrier (*Circus cyaneus*). I observed the goshawk in the midst of diving from above the harrier. The goshawk narrowly missed the harrier when the harrier moved out of the way just before the collision. This event occurred in a sagebrush dominated landscape near the Whiterocks River, Utah. It is unknown whether the goshawk was making a territorial attack or was hunting, but it appeared the goshawk was attempting to kill the harrier.

Discussion

During both field seasons, the two main prey species I found at kill sites were red squirrels and cottontail rabbits. I did not perform formal prey abundance surveys at winter ranges but general observations indicated cottontails were the most abundant prey species in pinyon/juniper woodlands at lower elevation winter ranges (~ 4500 – 7000 ft.). Pine squirrels appeared to be the most abundant prey species in mixed-conifer forests at higher elevation winter ranges (~ 7000 – 9500 ft). Even though goshawks primarily hunted those two species, I observed goshawks hunting prey in a variety of habitat types. The different habitat types included salt-desert scrub, sagebrush, pinyon/juniper, ponderosa pine, lodgepole pine, Douglas-fir, and subalpine fir. These results suggest that goshawks are a generalist species during the winter. This allows them to hunt a variety of habitats in order exploit a narrower prey base than is present in the nesting season.

Prior to my research, only one study has investigated prey selection of goshawks in the winter. Drennan and Beier (pers.comm.) reported for eight adult goshawks in Arizona, 6 Abert's squirrel (*Sciurus aberti*) and 21 desert cottontail (*Sylvilagus audubonii*) kills were located during the winter. No individual goshawk took both prey species and the results suggest that each individual specialized on a single large-bodied prey species. I found that red squirrels were the dominant prey species in winter ranges at higher elevations and cottontail rabbits were the dominant prey species in winter ranges at lower elevations. However, the goshawks I monitored did not appear to specialize solely on one species. Of the seven goshawks for which I found two or more kills, four goshawks killed at least two different species.

Goshawks exhibit reversed-size dimorphism. One of the theories to explain reversed dimorphism is that males and females are able to exploit a wider prey base through the size differences (Anderson and Squires 1997). This evolutionary trait would be expected to be most beneficial during the winter when the prey base is most limited. In Sweden, hares were the largest prey (2,700 – 3,670 g) goshawks were documented killing and they were also the only prey taken more frequently by females than males (Kenward et al. 1981). The female goshawks

I trapped averaged ~ 1100 g and the males averaged ~ 700 g. I did not observe prey partitioning between male and female goshawks but I did observe a high degree of dietary overlap. Red squirrels accounted for 42 % (5/12) of the kill sites I located for female goshawks and 36 % (4/11) of the kill sites I located for male goshawks. Cottontail rabbits accounted for 33 % (4/12) of the kill sites I located for female goshawks and 45 % (5/11) of the kill sites I located for male goshawks. The sample size of large-bodied prey (n = 3) I detected is too small to determine if any patterns in sexual partitioning of prey exists. However, it is interesting to note the largest prey I documented a male goshawk killing was a snowshoe hare (1.3 kg; Bittner and Rongstad 1982), while the largest prey I documented a female killing was a black-tailed jack rabbit (2.5 kg; Dunn et al. 1982).

Over-wintering strategies of goshawks may be related to food availability (Graham et al. 1999). One reason that 69% (9/13) of the marked goshawks migrated down in elevation may be due to the fact that red squirrel populations are hammered during the nesting season and there is higher prey availability in pinyon/juniper landscapes. A study in southcentral Wyoming documented that red squirrels were the dominant prey species delivered to nests by adult goshawks (Good 1998). Kill rates of European goshawks have been estimated at approximately twice every three days (Kenward 1979). Other studies estimate that goshawks may consume one-to-two prey per day (Reynolds et al. 1992). At these rates, red squirrel populations should be significantly decreased by the predation of nesting goshawks. In addition to lowered numbers of red squirrels, many of the other species goshawk hunt during the nesting season either migrate or hibernate during the fall. The result is a resource bottleneck in the mixed-conifer forests goshawks typically nest in. Thus, most of the goshawks I monitored migrated down in elevation to pinyon/juniper woodlands and made a diet shift to cottontails. A diet shift has been also been reported for goshawks in Sweden between the nesting season and winter (Widen 1987). During the nesting season, avian species were the dominant prey and squirrels were the dominating prey in winter.

A second advantage of migration and the dietary shift to cottontail rabbits is the energetic benefits. Cottontails (680–1,030 g) are approximately twice the size of red squirrels (145-260 g; Flyger and Gates 1982). Assuming that the energy expenditure of capturing a cottontail is equal to that of a red squirrel, the cottontail would give a higher return. Another energetic benefit of shifting to cottontails is related to the transport of the prey. Adult goshawks are no longer supplying food to their nestlings during the winter. Thus, adult goshawks are able to hunt larger prey items since they no longer constrained with the requirement of transporting prey from the kill site to the nest.

The implications of my results are that cottontail rabbits and the pinyon/juniper woodlands they occur in should also be recognized as important for wintering goshawks. Meeting the habitat requirements of wintering goshawks and their prey species could be just as important as meeting the needs of goshawks during the nesting season. Two species of cottontail occur in this region, desert cottontails (*Sylvilagus audubonii*) and mountain cottontails (*S. nuttallii*). Cottontails are generalist species that occupy many habitat types. Habitat recommendations for mountain and desert cottontails suggests that large downed woody debris, the base of rocks, and snags are available for nesting and escape cover (Reynolds et al. 1992). For foraging, well developed herbaceous and shrub layers are important (Reynolds et al. 1992).

Table 4.1 Diet of goshawks during the winter.

#	DATE	ID / SEX	PREY SPECIES	HABITAT
1	1/11/99	109 / F	Pine Squirrel	Aspen & Lodgepole
2	3/2/99	109 / F	Pine Squirrel	Fir
3	2/26/99	139 / M	Cottontail	Juniper
4	2/25/99	577 / F	Pine Squirrel	Lodgepole
5	2/28/99	577 / F	Pine Squirrel	Lodgepole
6	2/11/99	901 / M	Pine Squirrel	Cottonwood & Douglas-fir
7	2/17/99	931 / F	Cottontail	Pinyon & Juniper
8	3/11/99	931 / F	Pine Squirrel	Lodgepole
9	1/5/00	029 / M	Cottontail	Doug-fir
10	1/24/00	029 / M	Pine Squirrel	Doug-fir
11	2/29/00	049 / F	Cottontail	Pinyon & Juniper
12	12/18/99	069 / M	Ruffed grouse	Lodgepole
13	1/12/00	069 / M	Pine Squirrel	Lodgepole & Ponderosa
14	1/14/00	069 / M	Pine Squirrel	Subalpine fir
15	1/21/00	069 / M	Snowshoe hare	Aspen
16	12/19/99	228 / M	Cottontail	Doug-fir
17	1/24/00	228 / M	Cottontail	Doug-fir
18	3/1/00	228 / M	Cottontail	Juniper
19	12/21/99	972 / F	Cottontail	Juniper
20	12/29/99	972 / F	Black-tailed jackrabbit	Juniper
21	1/9/00	972 / F	European Starling	Sagebrush
22	3/6/00	972 / F	Black-tailed jackrabbit	Juniper
23	3/7/00	972 / F	Cottontail	Juniper

CHAPTER V

CAUSES OF MORTALITY FOR GOSHAWKS IN THE UINTA MOUNTAINS, UTAH

Introduction

The maximum life span of a wild goshawk is at least 11 years (Fowler 1985). It is probably uncommon for goshawks to reach that age though. In New Mexico, nestling survival varied from 100 % (6 nests) in 1992 to 37% at 8 nests in 1993 (Ward and Kennedy 1996). The highly variable nature of nestling survival is influenced by factors such as low prey availability and inclement weather. Mortality is believed to be highest during the first year after dispersal. In the first year of life, goshawks in Sweden and Finland are estimated to have a survival rate of 33% based on banding recoveries (Haukioja and Jaukioja 1970 in Squires and Reynolds 1997). A mark-recapture study (1991-1996) on the Kaibab Plateau, AZ, estimated annual survival of males (>1 yr-old) at 68.8% (SE = 0.07) and females (>1 yr-old) at 86.6% (SE = 0.05; R. T. Reynolds and S. M. Joy unpubl. data in Squires and Reynolds 1997).

Numerous causes of mortality have been reported for goshawks which include predation, starvation, trauma, disease, body parasites, and human caused mortality such as trapping, shooting, and poisoning (Squires and Reynolds 1997). Species that have been documented predating on adult goshawks in North America include great horned owls (*Bubo virginianus*; Boal and Mannan 1994), golden eagles (*Aquilia chrysaetos*; Squires and Ruggiero 11995), and pine martens (*Martes americana*; Paragi and Wholecheese 1994). Trauma includes mortality resulting from a goshawk colliding with objects such as other goshawks, trees, and the ground. Diseases reported for goshawks include tuberculosis (*Mycobacterium avium* infection; Lumeij et al. 1981 in Squires and Reynolds 1997) and erysipelas (*Erysipelas insidiosa* infection; Schroder

1981 in Squires and Reynolds 1997), *Chlamydia tsittaci* and *E. coli* (Ward and Kennedy 1996), and *Aspergillus* (Redig et al. 1980). Numerous internal and external body parasites have been documented on goshawks. Heavy infestations can cause a weakened body condition that might result in death.

The fourth objective of my research was to report the causes of mortality for wintering goshawks in the Uinta Mountains, Utah.

Methods

The transmitters that marked goshawks carried were instrumented with tipswitches as described in Chapters Two and Three. When a signal's pulse rate was fast for a period greater than 15 minutes and the signal intensity and direction remained constant, the goshawk was suspected to be dead. I then walked towards the signal until a visual observation was made. I made an effort to determine what the cause of mortality was when a dead goshawk was recovered. If the cause of mortality was not apparent, necropsies were performed at the Wyoming State Veterinary Laboratory in Laramie, WY.

Results

I monitored 18 goshawks and recovered six dead (3 M and 3 F) goshawks during two field seasons (Table 5.1). In the first field season, one of seven (14 %) goshawks died. During the second field season, five of fourteen (36 %) goshawks died and two transmitters were never located again after the goshawks were trapped.

Predators killed two goshawks. The first goshawk was a male and I suspect a pine marten killed him. The site was located in a stand of pinyon pines. Tracks were found at the site that appeared to be pine marten tracks. Tracking conditions were poor due to warm temperatures and limited snow so identification of the tracks was not positive. Feathers and the transmitter were all that was found at the site. I suspected the other predated goshawk, a female, was killed by a golden eagle, as golden eagles are common in this area. The location was along the west side of Flaming Gorge Reservoir in a juniper-sagebrush ecotone. The only remains of the goshawk I located were feathers and the transmitter. No bones were found. Within 10 feet of the spot where most of the feathers were located, I found defecation on the ground from what I suspect was a golden eagle.

The third mortality occurred to a male and was the result of trauma. The carcass was intact but a necropsy revealed the neck and right wing were broken. This suggested the goshawk died from a collision with the ground.

I suspect the fourth mortality was the result of old age. She was at least seven years old based on banding records. She was caught and banded as an adult in 1995. The bird was found in a pinyon stand and the carcass was intact. A necropsy revealed nothing usual other than enlarged ovaries. Her nest failed for unknown reasons the previous nest season.

The last two mortalities (2 M) exhibited similar characteristics to each other. Both carcasses were recovered in an emaciated state. Weight loss caused the transmitter harness to become loose, which resulted in friction that caused feathers under the harness system to fall out. Feather loss was minimal for both goshawks. The veterinarian who conducted the necropsies ruled out exposure from feather loss as the cause of mortality. The necropsies revealed nothing else abnormal so the evidence suggests these two goshawks died of starvation. The carcass of the first male was found in a pinyon/juniper stand. The carcass of the second male was found at the bottom of a steep canyon forested with Douglas-fir trees.

Discussion

The causes of mortality were difficult to determine because it was usually a couple days to several weeks before I located a carcass. Limited meaning can be interpreted from my observations due to the uncertainty associated with classifying the cause of mortality and a small sample size. However, if my classifications are correct and representative, predation and starvation could be significant forms of mortality for adult goshawks in this region during the winter.

A mortality rate for this population of goshawks is impossible to estimate due to the small sample size. However, if my results are representative of the population, survivorship of goshawks in the Uinta Mountains, Utah is similar to that of goshawks reported in other regions. I observed survivorship of male goshawks to be 50 % in year 1 (n = 2) and 50 % in year 2 (n = 4). Survivorship of female goshawks was 100 % in year 1 (n = 6) and 63 % in year 2 (n = 8). A mark-recapture study (1991-1996) on the Kaibab Plateau, AZ, estimated annual survival of males (>1 yr-old) at 68.8 % and females (>1 yr-old) at 86.6 % (R. T. Reynolds and S. M. Joy unpubl. data in Squires and Reynolds 1997).

Goshawk demography is poorly known which is apparent from the controversy over whether or not to list the goshawk as Threatened. Further research is needed to determine population size and structure, rate and direction of population change, age-specific survival and life span (Reynolds et al. 1992).

Table 5.1 Goshawk mortality.

DATE	ID / SEX	CAUSE OF MORTALITY
05/27/00	069 / M	Goshawk was emaciated. Transmitter harness was loose on the goshawk, which caused loss of feathers under the harness. Necropsy revealed nothing abnormal. Starvation is the suspected cause of mortality.
03/16/00	228 / M	Goshawk was emaciated. Transmitter harness was loose on the goshawk, which caused loss of feathers under the harness. Necropsy revealed nothing abnormal. Starvation is the suspected cause of mortality.
02/25/00	931 / F	Probably died of old age. She was at least 7 years old. Necropsy revealed nothing abnormal except her ovary was unusually hard.
02/22/00	011 / F	The suspected cause of mortality is predation by a golden eagle. The only remains of the goshawk at the site were feathers and the transmitter. Defecation from a raptor was clustered in three spots on the ground where most of the feathers were located.
12/09/99	189 / M	The carcass was intact but the neck and right wing were broken. The cause of mortality is unknown but was possibly caused from impact with the ground.
02/24/99	901 / F	The suspected cause of mortality is predation by a pine marten.

CHAPTER VI

Project Summary

As increasing amounts of mature forests throughout the western U. S. have been harvested, it has been suggested that goshawk populations are declining (Crocker-Bedford 1990). The U.S. Fish and Wildlife Service (FWS) has been petitioned to list the goshawk as Threatened. However, listing has been denied due to a lack of information documenting the speculated population decline. Controversy over the impacts of forest management and the status of goshawk populations has increased research efforts on this species. Most of the research has investigated goshawk habitat used for nesting and foraging during the nesting season. Management guidelines for goshawk habitat have been based on information derived from research performed during the nesting season. Efforts to manage goshawks need to consider both nesting season and winter habitat requirements (Squires and Ruggiero 1995). Limited information is currently available about whether goshawks migrate, what habitat they use, and their diet during the winter.

During the winters of 1998/99 and 1999/2000, I monitored 18 radio-telemetered northern goshawks. The objectives of my study were to determine the extent and timing of migration for goshawks, examine if goshawks select habitat at the micro-site and the landscape levels, describe the diet of wintering goshawks, and document the causes of goshawk mortality.

Of all marked goshawks, 73% were migratory. Forty percent of the males migrated and 90% of the females migrated. The average migration distance of male and female goshawks was 15 km and 68 km, respectively. The only obvious trend in the direction of migration was downwards in elevation. The timing of migration was not synchronous for all goshawks but it occurred between late October and mid-December in the fall. Goshawks returned to their nest stands between mid-January and late March.

Goshawks that migrated down in elevation made a diet shift to cottontails. Cottontails (n = 6) and black-tailed jackrabbits (n = 2) were the primary prey detected at kill sites at low elevation winter ranges (~ 4500 – 7000 ft.) and red squirrels (n = 9) were the primary prey detected on kill sites at high elevation winter ranges (~ 7000 – 9500 ft.).

Wintering goshawks demonstrated characteristics of a generalist species by using a wide variety of habitats. The only characteristic goshawks selected for at the micro-site scale was high canopy closure. No selection was observed for tree density, tree height, sapling density, shrub density, slope or aspect. At the landscape scale, the number of patches/km^2, vegetation types/km^2, and the length of forest edge was higher in goshawk home ranges than in random ranges but the difference was not statistically significant. Pinyon/juniper woodlands appeared to be an important habitat during the winter as most goshawks migrated to this habitat during part of the winter. Lodgepole pine, Douglas-fir, and pinyon/juniper woodlands were the dominant forest types present in goshawk core winter ranges.

Goshawk management efforts currently attempt to provide adequate habitat for goshawks based on nest season requirements. In Utah, no goshawk nests have been located in pinyon/juniper woodlands (Graham et al. 1999) so management efforts to maintain sustainable goshawk populations do not consider potential impacts to birds in this habitat. My results suggest that pinyon/juniper woodlands are important for goshawks during the winter. We are just now finding out that these woodlands are important and do not know the full extent of this dependency. Thus, management decisions regarding this habitat should consider the potential impacts to goshawk population viability.

The need to alter management efforts of nesting season habitats based on the results of this study is questionable. Current management practices in those areas attempt to manage for forests that are conducive to healthy prey populations and goshawk hunting during the nesting season. Squirrels are the dominant prey item in these habitats during both the nesting season and the winter. Therefore current management efforts for this habitat might be sufficient to meet the demands of goshawks during the winter also.

Literature Cited

Ashcroft, G. L., D. T. Jensen, and J. L. Brown. 1992. Utah Climate. Utah Climate Center, Utah State University, Logan.

Ashley National Forest. 1998. Northern goshawk monitoring information 1996-1998, Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Vernal, UT.

Beier, P. and J. E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7:564-571.

Bittner, S. L., O. J. Rongstad. 1982. Snowshoe hare and allies. Pages 146-166. *In* Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland. 1147p.

Bloom, P. H., J. L. Henckel, E. H. Henckel, J. K. Schmutz, B. Woodbridge, J. R. Bryan, R. L. Anderson, P. J. Detrich, T. L. Maechtle, J. O. McKinley, M. D. McCrary, K. Titus, and P. F. Schempf. 1992. The dho-gaza with Great Horned Owl lure: an analysis of its effectiveness in capturing raptors. Journal of Raptor Research 26:167-178.

Bloxton, T. D. and J. H. Delap. 1998. Winter movements of northern goshawks in western Washington. Abstracts of the Raptor Research Foundation 1998 Annual Meeting, Ogden, Utah, Sept 30 – Oct 4 1998.

Boal, C. W. and R. W. Mannan. 1994. Northern goshawk diets in ponderosa pine forests on the Kaibab Plateau. Studies in Avian Biology. 16:97-102.

Bright-Smith, D. J. and R. W. Mannan. 1994. Habitat use by breeding male northern goshawks in Northern Arizona. Studies in Avian Biology 16:58-65.

Cottam, G. and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Crocker-Bedford, D. 1990. Goshawk reproduction and forest management. Wildlife Society Bulletin 18:262-269.

Drennan, J. E. and P. Beier. 2001. [Personal communication]. Garcia and Associates, 248 San Carlos Street, San Francisco, California and School of Forestry, Northern Arizona University, Flagstaff , Arizona.

Dunn, J. P., J. A. Chapman, and R. E. Marsh. 1982. Jackrabbits. Pages 124-145. *In* Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland. 1147p.

Good, R. 1998. Factors affecting the relative use of northern goshawk (*Accipiter* gentilis) kill areas in southcentral Wyoming. M.S. thesis. University of Wyoming, Laramie.

ESRI. 1996. Using ArcView GIS. ESRI, Redlands, CA.

Evans, D. L., and C. R. Sindelar. 1974. First record of the goshawk for Louisiana – a collected, banded bird. Bird-Banding 45:270.

Flyger, V. and J. E. Gates. 1982. Pine Squirrels. Pages 230-238. *In* Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland. 1147p.

Graham, R. T., R. L. Rodriguez, K. M. Paulin, R. L. Player, A. P. Heap, R. Williams. 1999. The northern goshawk in Utah: habitat assessment and management recommendations. Gen. Tech. Rep. RMRS-GTR-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 48p.

Hagris, C. D., C. McCarthy, and R. D. Perloff. 1994. Home ranges and habitats of northern goshawks in Eastern California. Studies in Avian Biology 16:66-74.

Ingraldi, M. F. 1998. Population biology of northern goshawks in east-central Arizona. Nongame and Endangered Wildlife Program Technical Report 133. Arizona Game and Fish Department, Phoenix, Arizona.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kennedy, P. L. 1997. The northern goshawk (*Accipiter gentilis atricapillus*): Is there evidence of a population's decline? Journal of Raptor Research 31:95-106.

Kenward 1982. Goshawk hunting behaviour and range size as a function of food and habitat availability. Journal of Animal Ecology 51:69-80.

Kenward, R. E., V. Marcstrom, M. Karlbom. 1981. Goshawk winter ecology in Swedish pheasant habitats. Journal of Wildlife Management 45:397-408.

Kirkley, J. 1999. Foraging and roosting habitats of overwintering northern goshawks (*Accipiter gentilis*) in Southwestern Montana. *In* Proceedings from the Raptor Research Foundation Annual Meeting. La Paz, Baja California Sur, Mexico. 72p.

Merrill, E.H. T.W. Kohley, M.E. Herdendorf, W.A. Reiners, K.L. Driese, R.W. Marrs , S.H. Anderson. 1996. Wyoming Gap Analysis: a geographic analysis of biodiversity. Final Report, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, WY.

McKlosky, J. T. and S. R. Dewey. 1999. Improving success of a mounted Great Horned owl lure for trapping northern goshawks. The Journal of Raptor Research 33:168-169.

Mueller, H. C., D. D. Berger, and G. Allez. 1977. The periodic invasions of goshawks. The Auk 94:652-663.

National Geographic Society (US). 1999. Birds of North America, third edition. National Geographic Society, Washington D.C. 480p.

Paragi, T. G., and G. M. Wholecheese. 1994. Marten, *Martes americana*, predation on a northern goshawk, *Accipiter gentilis*. Canadian Field Naturalist. 108:81-82.

Redig, P. T., M. R. Fuller, and D. L. Evans. 1980. Prevalence of *Aspergillus fumigatus* in free-living goshawks (*Accipiter gentiles atricapillus*). Journal of Wildlife Diseases 16:169-174.

Reynolds, R. T., E. C. Meslow, and H. M. Wight. 1982. Nesting habitat of coexisting Accipiter in Oregon. The Journal of Wildlife Management 46:124-138.

Reynolds, R. T., E. C. Meslow. 1984. Partitioning of food and niche characteristics of coexisting Accipiter during breeding. Auk 101:761-777.

Reynolds. R. T., R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce, G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the Northern Goshawk in the southwestern United States. USDA Forest Service General Technical Report RM-217.

Squires, J. R. 1997. [Personal communication]. U.S. Department of Agriculture, Forest Service, Missoula, Montana.

Squires, J. R., and R. T. Reynolds. 1997. Northern Goshawk (*Accipiter gentilis*). *In* The Birds of North America , No. 298 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C. 32p.

Squires, J. R., and L. F. Ruggiero. 1995. Winter movements of adult Northern goshawks that nested in Southcentral Wyoming. Journal of Raptor Research 29:5-9.

USGS National Gap Analysis Program. 1995. Utah gap analysis data. On file at: Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, UT.

Ward, J. M., and P. L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile northern goshawks. Auk 113:200-208.

Watson, J. W., D. W. Hays, and S. P. Finn. 1998. Prey of breeding northern goshawks in Washington. The Journal of Raptor Research 32:297-305.

Welty, J. C. and L. Baptista. 1990. The Life of Birds. Saunders College Publishing, New York. 581p.

Widen. 1989. The hunting habitats of Goshawks *Accipiter gentilis* in boreal forests of central Sweden. Ibis 131:205-231.

Widen. 1987. Goshawk predation during winter, spring, and summer in a boreal forest area of central Sweden. Holarctic Ecology 10:104-109.

Widen. 1985. Breeding and movements of goshawks in boreal forests in Sweden. Holarctic Ecology 8:273-279.

Widen. 1984. Activity patterns and time-budget in the Goshawk *Accipiter gentilis* in a boreal forest area in Sweden. Ornis Fennica 61:109-112.

Widen. 1981. Activity pattern of goshawks in Swedish boreal forests. Pages 114 – 120 *In* Understanding the goshawk. (R. E. Kenward and I. M. Lindsay eds.). The International Association for Falconry and Conservation of Birds of Prey, Oxford.

Appendix A. 1998/1999 Migration patterns

During the first field season, six of seven marked goshawks were tracked to their winter ranges (Table 1). The seventh goshawk disappeared at the end of October 1998 and did not return to her nest territory until the end of February 1999. Six of the seven (86%) goshawks left their nest territory during the winter. The average migration distance for the two males was ~ 15 km and the average migration distance for the four females was > 80 km. Both males established winter ranges ~ 15 km from their nest stands. Two females migrated ~ 70 km, a third female migrated ~ 80 km, a fourth female migrated further than 100 km to an unknown winter range, and the fifth female wintered at her nest territory (don't include non-migratory bird in average?).

Eighty percent (4 of 5) of the migratory goshawks with a known destination wintered at lower elevations than their nest stands. Sixty six percent (4 of 6) of the sample of marked birds wintered at lower elevations than their nest stands. The two males wintered at lower elevations than their nest stands. Both males migrated to the S and SW. Of the three females for which the migration destination is known, two wintered at lower elevations than their nest stand and one wintered at similar elevations to her nest stand. The direction from the nest stand for the four migratory females was east, west, southwest, and unknown.

The initiation of the migration was distributed over a period of time, which ranged from late October to late December. One male migrated in early November and the other male migrated in early December. Of the four migratory females, one left in late October and the other three migrated during December.

Four of the five migratory goshawks returned between Feb 24 and Mar 18. The date of return to nest territory for all five migratory goshawks ranged from Jan 07 to Mar 18. One male returned to his nest territory between Mar 10 and Mar 14 and the other male was found dead on his winter range on Feb 24; however, this male was located back in his nest territory three times during the winter. The first female returned to her nest territory on Jan 13, two other females were found back in their nest territories on Feb 28, and the other migratory female was found back in her nest territory on Mar 18.

The duration of fall migration is reported as the time that a bird spent migrating between the nest territory and the winter range. It was difficult to estimate because marked goshawks were often not observed for a period of time once they left their nest stands until they were located at a winter range. I defined this aspect of migration as the interval between the last time a goshawk was located in the nest territory and the first time located on the winter range. For the two males, this interval was within four days and eight days. Of the three females tracked to their winter ranges, the interval was three weeks, three weeks, and five weeks.

The duration of spring migration is reported as the time interval between the last location on the winter range and the first location back at the nest territory. A male returned to his nest territory in a maximum of four days. The three females tracked from their winter ranges to their nest stands returned in a maximum of four, four, and seven days. I estimate the average time goshawks spent on their winter range was 85 days (Table 3). Time spent at a winter range is only estimated for migratory goshawks and is estimated as the interval between the median fall migration date and the median spring migration date.

Winter ranges appeared to be well defined for most migratory birds. During 1998/99, 4 goshawks had well developed winter ranges, one was a floater, and two did not have enough locations to determine a winter home range.

Appendix B. 1999/2000 Migration Patterns

I tracked eleven of fourteen goshawks to their winter ranges during the second field season (Table 2). Eleven goshawks were new to the study and three were also tracked during the first field season. I located eleven of the marked goshawks on their winter ranges during the 1999 – 2000 field season. I never found two birds again after they were trapped in 1999 and we found one dead on 12/09/99 near his nest territory.

Nine of the eleven goshawks (82%) located on winter ranges migrated away from their nest stands. I found two males on winter ranges ~ 15 km from their nest stands and the other two remained in their nest territories throughout winter. All seven females were migratory and the average migration distance of was ~ 63 km (n = 7; range = 8 – 100 km). Eight of the eleven goshawks (73%) wintered at lower elevations than their nest stands. One male migrated south and down in elevation and the other male migrated east and stayed at elevations similar to his nest stand. All seven females migrated down in elevation. Their direction of migration was one to the north, two to the east, one to the southeast, one to the south, and two to the southwest.

The two migratory males arrived at their winter ranges between Nov 3 and Nov 17. One died during the winter and the other male returned to his nest territory once on Feb 4 before he returned permanently sometime between Mar 8 – Mar 23. The seven females migrated between Nov 3 and Dec 23. Late November through mid-December was the period of highest migratory activity for the females. Two females died during the winter and the other five females all returned to their nest territories between Jan 13 and Mar 23. Two of the females returned to their nest territories during the last two weeks of January, one returned during the last week of February, and the other two returned between the second and third weeks of March. One of the females was located in nest territory on Feb 8, back at her winter range on Feb 15, and then back in the nest territory in mid-March.

The interval between the last location in a marked bird's nest stand and the first location at a winter range was short for most goshawks. The migration interval of four marked goshawks was between 2 – 7 days. The migration interval was not possible to estimate for the other migratory goshawks because we either did not start tracking them until after they had already migrated to their winter range, or because they were not located for long periods of time. The duration of spring migration for the one male was a maximum of 15 days during his final return to the nest territory. The duration of migration for five females was a maximum of 6, 11, 14, 15, and 16 days.

The average time spent at the winter range for migratory goshawks was 82 days (Table 4). Winter ranges appeared to be well defined for most goshawks. During 1999/00, eight goshawks had well developed winter ranges, two were floaters, and four did not have enough locations to determine a winter home range.

Appendix C. Movements of individual goshawks during 1998/1999

<u>*Goshawk 150.109*</u> This female spent the entire winter in the general area of her nest territory in Bowden Draw. The furthest she was ever located away from her nest was 3.2 km.

<u>*Goshawk 150.139*</u> This male migrated ~ 10-15 km south of his nest stand and down in elevation. His winter range is along the Whiterocks River north of the town of Whiterocks. He arrived at his winter range by 11/5/98 and he returned to his nest territory by 3/14/99.

<u>*Goshawk 150.457*</u> This female spent most of the winter south of Mountain View, Wyoming in the Sage Creek drainage area. This winter range is approximately 70 km west of her nest and it is at a similar elevation. She was last located in her nest territory on 12/23/98 and first located on her winter range on 1/28/99. Her signal was first located at her nest territory on 3/18/99.

<u>*Goshawk 150.577*</u> This female spent the majority of the winter in the Dry Fork Creek drainage, which is the drainage her nest is located in. Sometime after 12/3/99 she moved from Dry Fork Creek to the northeast and was located as far away as the Wyoming/Utah state line to the east of Hwy 191 on 12/23/99. This area is ~ 60 to 75 km from the nest stand. Her signal was received back in Dry Fork Creek on 1/13/99 and remained there for the rest of the winter.

<u>*Goshawk 150.698*</u> This female migrated sometime after 10/26/98 and her signal was received back at the nest stand on 2/28/99. Where she spent the winter is unknown. An intensive, aerial search covering a radius of at least 100 km from her nest was performed several times over the winter. No signal was ever received. It is likely that she wintered greater than 100 km from her nest.

<u>*Goshawk 150.901*</u> This male had two distinct winter ranges that he alternated between during the winter. One was in the same drainage as his nest stand, Dry Fork Creek, but at lower elevations. The other winter range was ~ 15 km to the south southwest in Whiterocks River

drainage and at lower elevations than the nest stand. He spent the majority of his winter in pinyon/juniper and limber pine forests. He was last found in his nest territory on 12/03/98 and first found in the Whiterocks River drainage on 12/7/98. He was located back in the Dry Fork Creek drainage between the dates of 12/18/98 to 12/22/98 and then found back in the Whiterocks River drainage on 1/6/99. He bounced back and fourth between the two drainages two more times between 1/23/99 and 2/8/99. He stayed in the Whiterocks River drainage for the rest of the winter until he was found dead on 2/24/99.

Goshawk 150.931 This female migrated ~ 80 km south of her nest and down in elevation. She probably crossed over the Uinta Mountains during migration. The winter range is near Mountain Home, Utah. We last located her in her nest territory on 12/02/98 and first located her on 12/22/98 in her winter range. She returned to Cub Creek by 2/28/99.

Appendix D. Movement of individual goshawks during 1999/2000

Goshawk 150.011 This transmitter emitted a poor signal so we only collected marginal data on this female. We last located her in her nest territory on 12/08/99. She migrated down in elevation to a winter range ~ 8 km NE of Manila, Utah and adjacent to Flaming Gorge Reservoir. Her winter range was ~ 20 km north of her nest territory. She was found dead in her winter range on 2/22/00.

Goshawk 150.029 This male spent the entire winter on his nest territory. The furthest he was ever located from his nest during the winter was 10 km.

Goshawk 150.049 This female was last found in her nest territory on 11/16/99 and was initially found on her winter range on 12/09/99. Her winter range was located along the Lake Fork River ~ 5km north of Mountain Home, Utah. The winter range was ~ 25 km SE and down in elevation from her nest stand. She was located back at her nest on 2/08/00 and subsequently found back at her winter range on 2/15/99. She remained on her winter range until she was located back in her nest territory on 3/23/00.

Goshawk 150.069 This male spent the entire winter on his nest territory. The furthest he was ever located from his nest stand during the winter was 9 km.

Goshawk 150.089 This female was never located again after the transmitter was placed on her.

Goshawk 150.139 This male migrated to the same winter range he was found on last winter. His winter range is along Whiterocks River north of the town of Whiterocks. The area is ~ 10-15 km south of his nest stand and down in elevation. He arrived at his winter range by 11/03/99. He was last found on his winter range on 3/08/00 and found back in his nest territory 3/23/00.

Goshawk 150.169 The transmitter on this female replaced transmitter 150.577 from the previous year. Her movement patterns this winter were similar to those from last winter but she spent a longer period of time away from her nest territory in Dry Fork Creek. She left her nest territory in Dry Fork Creek after 12/13/99. She migrated to the east and was located as far away as 70 km. She did not have a well defined winter range but she typically used landscapes at a lower elevation than her nest stand. She returned by 2/01/00 to the Dry Fork Creek drainage and spent the rest of the winter there.

Goshawk 150.189 This male was found dead on 12/09/99 close to his nest stand. He was recovered ~ 7 km south of his nest stand.

Goshawk 150.209 This female was last found in her nest stand on 12/16/99. She was first found on her winter range on 12/23/99, which is an area along the White River slightly to the west of Bonanza, Utah. She migrated ~ 90 km south of her nest and down in elevation to her winter range. She left the winter range sometime after 2/23/00 and returned to her nest stand sometime before 2/29/00.

Goshawk 150.228 This male left his nest stand before 11/17/99. His winter range was ~ 7-20 km east of his nest stand and at similar elevations. The winter range was large and included the area from Manila east to the Flaming Gorge, south to the junction of Hwy 44 and Carter Creek, and west to Summit Springs guard station and NW to Jessen Butte. There was no apparent change in elevation of habitat between summer and winter use. He was found dead on 3/16/00 approximately 20 km east of his nest stand.

Goshawk 150.269 This male was never located again after the transmitter was placed on him.

Goshawk 150.779 This female migrated east of her nest stand. During her migration she did not establish a definable winter range. She was first found away from her nest stand (~ 25 km) on 12/18/99. On 12/23/00 she was located ~ 50 km east of her nest stand. From 12/30/00 to 1/04/00 and she was in an area ~ 100 km east of her nest stand and at a lower elevation. On

1/13/00 she back to the area ~ 50 km east of the nest stand. From 1/24/00 through the rest of the winter, she was in the general area of her nest territory.

Goshawk 150.931 This female left her nest territory prior to 11/11/99. She used the same winter range as the previous year and she arrived there by 12/04/99. The winter range is ~ 85 km to the SW and down in elevation. She was found dead on 2/25/00 in her winter range.

Goshawk 150.972 This female left her nest territory before 11/03/99 and arrived at her winter range before 12/09/99. She migrated ~ 65 km to the SW and down in elevation. Her winter range was ~ 5 km west of Roosevelt, Utah. She left her winter range by 3/08/00 and returned to her nest territory by 3/22/00.